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Fabrication and non-linear measurements of a GaInAs/InP electron waveguide T-branch switch

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Devices based on electron waveguide phenomena attracted considerable interest during the last several years. Because of high velocity of electrons in the waveguides, these devices seem to be very promising for high speed electronics. Besides, they potentally allow extremely low power dissipation. The complicating factor, however, is a large impedance (13 kOhm for a single mode operation) of the electron waveguide devices, thus restricting their switching speed. Even though the potential for extreme speed (more than 100 GHz) operation might be limited, there is a need for investigation of high frequency limitations of such structures.

Here we present fabrication technology as well as DC and high-frequency (HF) characterization of an electron waveguide based GaInAs/InP T-branch switch (TBS). The TBS-device is formed by 3 reservoirs separated by three quantum point contacts (QPC); each of the QPCs is connected to a three port terminal device, Fig. 1. The device is fabricated using a high mobility 2DEG GaInAs/InP structure with a pseudomorphic $Ga_{0.25}In_{0.75}As$ QW

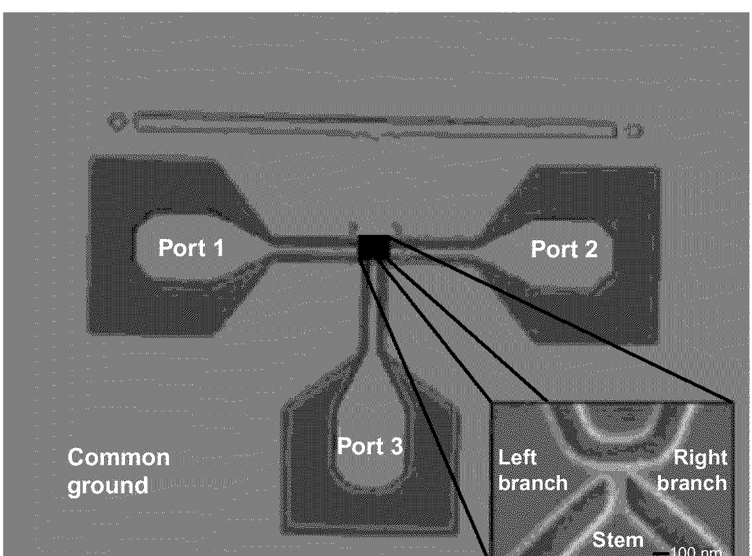

Fig. 1. Microwave pad design with SEM image of T-branch structure. HF-pads are optimized to have a parasitic signal crosstalk of less than −50 dB for frequency of up to 7 GHz.

positioned 40 nm below the InP cap layer. The 2DEG mobility and electron concentration in the GaInAs QW are 450 000 cm^2/Vs and 6-8$\times 10^{11}$ cm^{-2} at 0.3 K, respectively. High-resolution electron beam lithography operating at 35 kV was used to pattern ZEP520A7 positive tone resist to form a mask for wet etching. After a post development baking of the resist [ ], a non-selective HBr-based etchant was used to define the TBS-device. Etching was performed down to InP substrate (about 80 nm in depth) in order to prevent parasitic leakage current from the active device area. Geometrical width of the waveguides in the device was about 150 nm, no epitaxial regrowth was applied.

The T-branch switch was fabricated on a coplanar microwave pad layout optimized for HF-measurement, Fig. 1. Pad-to-pad capacitance is 0.4 and 0.7 fF from port 1 to 2 and from port 1 to 3, respectively, which gives a required isolation of 50 dB (due to the high

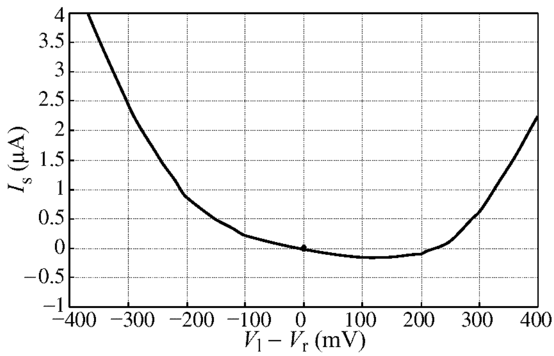

Fig. 2. Room temperature dependence of the stem current versus voltage difference between left and right branch ($V_l - V_r$). The stem is connected to ground ($V_s = 0$).

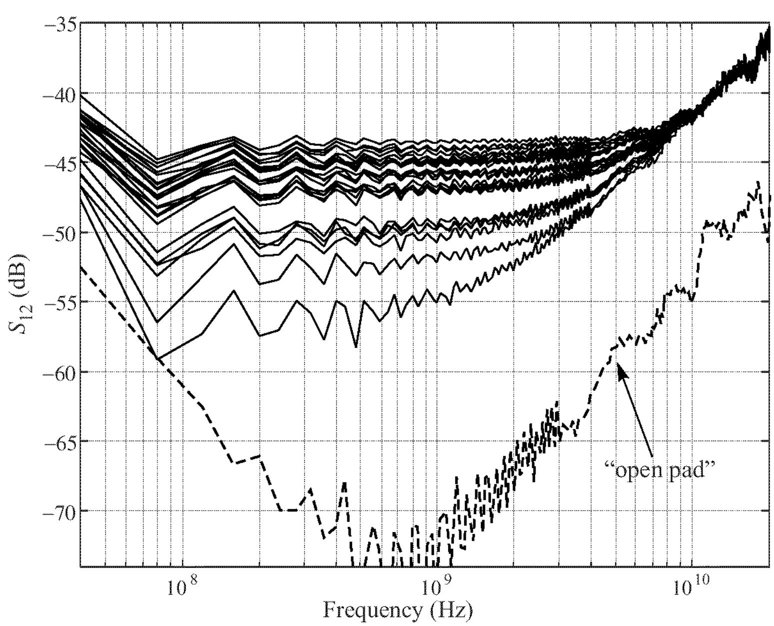

Fig. 3. Scattering parameter S_{12} measured at different biases (upper group of curves) on TBS-device at room temperature. "Open pad" measurement without T-branch device is also shown.

impedance nature of EWG structures) up to approximately 7 GHz.

According to theory [2] and previously made measurements on Y-branch structure [3], [4], the TBS-device can be used as a rectifier with voltages V_l and V_r applied to the left and the right branch in a push-pull mode ($V_l = -V_r$). Under these conditions, the stem voltage V_s is always negative and depends approximately quadratic at small V_l and V_r. This non-linearity originates from the ballistic electron transport between the reservoirs. Electron mean free path at 300 K is about 200 nm, which equals or slightly larger than the distance between the QPCs. Figure 2 shows the room temperature measurements of the stem current as a function of voltage difference on branches $V_l - V_r$. We demonstrated that this non-linearity effect could be used as a frequency mixer. The measured signal power spectrum of the TBS-device corresponds well to the expected quasi-DC response with an applied signal frequency of up to 300 MHz and second harmonic of 600 MHz. Signal transmission from the right branch to the left branch (parameter S_{12}) was measured as a function of DC bias of ports 1 and 2 for different frequencies. The stem electrode was connected to ground via a 50-Ohm resistor. The S_{12} scattering parameter indicates a clear non-linear (DC dependent) behavior up to about 3 GHz, above this frequency the signal is limited by a parasitic capacitance leakage between the ports, see Fig. 3. Prior to HF-measurement of the TBS-device, both "open pad" and "through" structures without the device were characterized for calibration purposes. All the HF-measurements were performed at room temperature using 50-Ohm loads.

Acknowledgements

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